The Wheel Versus Track Dilemma

by Paul Hornback

With the development of any new Army combat vehicle, the question, "Which is better: a wheeled vehicle or a tracked vehicle?" surfaces again and again. In order to answer this question, the U.S. Army has tested and studied the merits and shortfalls of wheeled and tracked combat platforms for the past 30 years. Results indicate that no single criterion can be applied that will answer the wheeled-versus-track issue for all situations and missions. In fact, the underlying premise in resolving the wheeled-versus-track dilemma is deeply rooted in the complex variables regarding the platform's combat mission, terrain profile, and specific vehicular characteristics. Tests and studies, however, established a set of criteria to determine a platform's optimal configuration. Although most of this information is over ten years old, the basic factors which impact the physics of mobility have not changed and are still relevant.

MOBILITY. Mobility, as defined by the 1988 Mobility Analysis for the TRADOC Wheeled-Versus-Track Study, is the ability to move freely and rapidly over the terrain of interest to accomplish varied combat objectives.[1] Mobility is thus measured by a system's freedom of movement (percent of the terrain over which the vehicle is mobile) and its average speed or travel time over that terrain. A platform's gross vehicle weight and its footprint (the area of track or tire which impacts the ground) determine the resultant ground pressure that the platform imparts on the soil. The soil strength, coupled with the vehicle's characteristic ground pressure, determine a parameter entitled Vehicle Cone Index (VCI), which is a key first-order discriminator of a platform's mobility. The higher the VCI, or ground pressure, the less mobile the platform becomes. Figure 1 shows that, as ground pressure increases, so does the percentage of No-Go Terrain (terrain over which a combat platform is immobile) due to traction loss in wet, temperate areas.

A vehicle's mobility is impacted by its tractive ability over various soil types (dry, wet, sand, or snow-covered) and its ability to maneuver over obstacles, cross gaps, and negotiate varied vegetation. As a general rule of thumb, a lower VCI not only equates to better soft-soil mobility but also indicates better performance on slopes, in sandy terrain, over obstacles/gap crossings and when overriding vegetation.[2] From a mobility perspective, *tracked vehicles offer the best solution for a versatile platform that is required to operate over diverse terrain, including extremely difficult ground,* because tracks inherently provide a greater surface area than wheels, resulting in a lower VCI.[3] Recent operations in Bosnia have demonstrated the inherent weaknesses of wheeled vehicles with regard to mobility and protection.[4] When operations were conducted on roads, wheeled vehicles demonstrated excellent mobility and speed; but when off-road usage was required, and wet or snow conditions prevailed, mobility suffered.

Wheeled vehicles inherently attain faster road speeds and, therefore, offer the best solution where unrestricted mobility is not the primary mission driver and on-road usage exceeds off-road usage. So, vehicle weight and off-road usage constitute two key criteria for mobility. Figure 2 compares the average 100 km mission travel time for both wheeled and tracked platforms as off-road usage increases (recall that mobility was defined as both freedom of movement and travel time over the terrain).

As off-road usage dominates the vehicle's profile, tracked configurations provide significantly better mission travel times. Consequently, Army studies indicate that when a vehicle's mission requires off-road usage greater than 60 percent and gross vehicle weight exceeds 10 tons, a tracked configuration is preferred for combat roles.[6] However, when the gross vehicle weight exceeds 20 tons and off-road usage remains above 60 percent, a tracked configuration is required to guarantee the best mobility for unrestricted, all-weather tactical operations.[7]

SURVIVABILITY. A combat platform's survivability is dependent on numerous criteria, to include mine and ballistic protection, size/silhouette, and stealthiness. Tracked vehicles, by design, are inherently more compact than wheeled vehicles.[8] The primary reasons for a tracked vehicle's compactness are reduced suspension clearance, wheel turning clearance, and the absence of multiple transfer cases and drive shafts that are integral to the design of multi-wheeled vehicles. Army studies have indicated that, for a comparable VCI (or ground pressure) at the same gross vehicle weight, wheeled platforms require up to six times more volume for drive train and suspension components than tracked platforms. This results in up to a 28 percent increase in vehicle volume if the same interior volume is maintained.[9] Survivability analyses clearly indicate that a larger size is more readily seen and subsequently hit and destroyed. Additionally, as a combat platform's size increases, so does the gross vehicle weight (provided the same ballistic and mine protection are maintained), which tends to degrade vehicle mobility and deployability.

In general, wheeled platforms are more vulnerable to small arms fire and grenade, mine, and artillery fragments, due to the inherent weakness of wheeled suspension designs, components, and tires.[10]

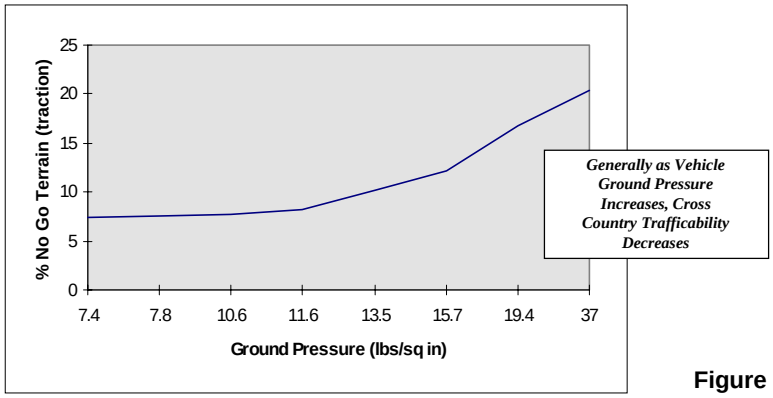

Figure 1

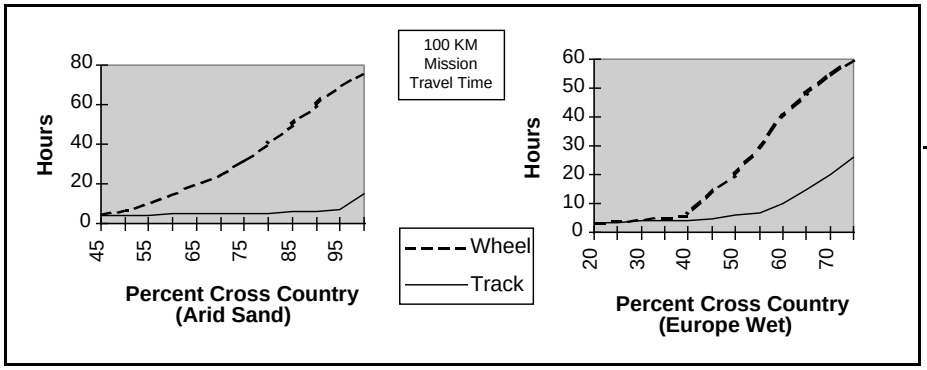

Figure 2[5]

Wheeled vehicles may now be able to continue movement for limited distances at reduced speeds when tires are punctured by small arms rounds, battlefield debris, or shrapnel, due to the advent of run-flat tires. Run-flat tires typically contain a hard rubber insert (some with nitrogen filled cells) inside the tire. The insert bears no vehicle load until the tire is punctured, at which point the load is transferred to the insert and vehicle movement may continue for a limited distance and speed.

On the plus side, wheeled platforms provide a reduced noise signature while moving, primarily due to less vibration and metal to metal contact on running gear. Improvements in track technology (i.e., Roller Chain Band Track) and decoupled running gear have decreased noise signatures for tracked vehicles, but not to the level attained by wheeled platforms.

Tracked platforms do provide a skid-steer capability which allows the vehicle to pivot steer (or neutral steer) and virtually pivot in place. This unique maneuver capability enhances survivability by permitting a 180-degree directional change when confined or built-up areas are encountered, and while traveling on narrow road surfaces.

Study Results	*Tracked Vehicles*	*Wheeled Vehicles*
Route Flexibility	✔	
Cross Country Mobility	✔	
Traction on Slopes	✔	
Road Speed		✔
Logistics		✔
O&S Costs		✔
GVW, Volume, & Payload	✔	
Maneuverability/Turning Radius	✔	
Transportability	✔	
Weight Growth Potential	✔	
Gap & Obstacle Crossing	✔	

Figure 3

From a survivability perspective, *tracked vehicles offer smaller silhouettes, reduced volume, enhanced maneuverability, and better ballistic protection, providing a balance that equates to a more survivable platform.*

SUPPORTABILITY. A combat platform's supportability is dependent on numerous factors, to include fuel usage, reliability, and O&S costs. Wheeled vehicles traditionally offer better fuel economy due to the reduced friction losses inherent in wheel/tire suspensions and running gear. The better fuel economy translates into smaller on-board fuel storage requirements or greater operating ranges for wheeled platforms.

Previous articles and studies have concluded that wheeled vehicles are intrinsically more reliable than tracked vehicles and, therefore, require less maintenance and supply support (spare parts). However, one must bear in mind that wheeled vehicles generally have a higher percentage of on-road usage while tracked vehicles incur more off-road usage. Obviously, the more severe cross-country terrain results in reduced reliability for the tracked vehicle. A recent test of the Up-Armored HMMWV, running a scout profile with 68 percent off-road travel, resulted in significantly lower reliability when compared to the same platform running at a tactical truck profile of only 40 percent off-road.

Given that wheeled platforms offer better fuel economy and reliability (to an extent), then Operating and Support (O&S) costs are lower than those demonstrated by tracked platforms. This makes wheeled platforms excellent candidates for support roles where overall mileage is high and primarily conducted on-road.

CONCLUSION. Figure 3 presents an overview of the key advantages demonstrated by wheeled and tracked platforms based on thirty years of Army tests and studies.

Wheeled and tracked vehicles each exhibit advantages that can be optimized for the 21st century battlefield, provided the platform's combat mission, terrain profile and specific characteristics are carefully assessed. For combat vehicles, vice combat support or combat service support vehicles, Army studies unanimously conclude that a tracked configuration is the optimal solution for tactical, high-mobility roles (off-road usage greater than 60 percent), gross vehicle weights in excess of 20 tons, and missions requiring unrestricted terrain movement, continuous all-weather operations, smaller silhouettes/dimensional envelopes, and greater survivability.

Notes

[1]"Mobility Analysis for the TRADOC Wheeled Versus Track Vehicle Study, Final Report," Robert F. Unger, Geotechnical Laboratory, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss., September 1988, 1.

[2]Ibid, 26.

[3]"Wheels or Tracks," *Military Technology*, Vol XVIII, Issue 7, Jul 1994, 14.

[4]"Is There Any Future for the APC," *Military Technology*, Vol. XXI, Issue 3, March 1997, 103.

[5]"Mobility Analysis," 48.

[6]"Wheeled Versus Track Vehicle Study, Final Report," Studies and Analysis Activity, Headquarters U.S. Army Training and Doctrine Command, Fort Monroe, Va., March 1985, 1-99.

[7]Ibid, 1-92.

[8]Ibid, 1-62.

[9]Ibid, 1-62.

[10]"Wheels or Tracks," 11.

Mr. Paul Hornback is a general engineer with the federal government. He is presently assigned to the HQ TRADOC Combat Development Engineering Division, Fort Knox Field Office, which provides reliability, maintainability, and systems engineering support to the Directorate of Force Development, Fort Knox, Ky. He holds a Bachelor of Science in Mechanical Engineering and a Master of Science in Industrial Engineering, both from the University of Louisville. His military experience stems from a six-year tour as a UH-1N helicopter pilot in the U.S. Marine Corps.